DIAGNOSING AND OVERCOMING URBAN SOIL PROBLEMS

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Urban soil situations present a myriad of problems for the landscape architect, related professionals, and property managers because of their complexity and their past management practices. Natural soils, as they occur on a landscape, can be mapped and interpretive information readily provided by an experienced agronomist or soil scientist. However, once humans have had the opportunity to manipulate soil, remove trees, cut and fill areas, develop and industrialize areas, significant alterations occur to the soil. There is no longer much rhyme or reason to their occurrence on the landscape and any similarities with their natural counterparts is coincidental. This paper will provide an introduction to developing urban sites, a discussion of urban soils, approaches to amend soils, alternative planting schemes, and discuss site management.

SPECIFICATIONS / INSPECTION

It is very important to have a through and detailed set of specifications and an informed site inspector available during all phases of planning and construction to insure that the project remains on schedule and as designed. This individual must have the authority to halt the project should the conditions warrant.

Early during the planning phase, it is important to determine the design life for the site. Also, consider the maintenance required to allow the design to mature gracefully. Will the available personnel be able to maintain the design once created? Are there specific maintenance techniques or personnel requirements? Can these needs be met? If these questions can not be answered positively, then it would seem prudent to scale down the design. It makes no sense to create a feature that looks great at dedication but begins to decline soon thereafter.

SITE ASSESSMENT

Before a site is developed, it is essential that a detailed site investigation be conducted to determine the extent of soil profile heterogeneity, its condition, and other site irregularities. A complete soil testing program may be necessary to fingerprint anomalies. If a site has been recently converted from farm land, it is likely that the soil can be utilized much as it occurs. However, if the site had been manipulated to any extent, and this is usually the case, the soil will likely require amendments to provide a suitable medium for the selected landscape plants. In the worst case, the material may have to be removed entirely from the site, or the landscaping built above the poor soil. In either instance, the cost of development will be high.

When conducting a detailed site analysis, it is important to open one or more soil pits to observe horizonation and continuity of the soil across the site. While opened, each pit should be closely observed for color differences. If there are zones of gray or gleyed soil, mottled soil colors, or standing water, then drainage will be a problem. Also, by using the sense of smell, one can tell if anaerobic or septic conditions exist. Observe the profile for artifacts of human activity such as brick, concrete, etc. Look for lithologic discontinuities or horizons of widely differing characteristics such as soil texture and density. These conditions indicate that extensive human manipulation may have occurred. Observe the extent or lack of plant roots and their condition. Are the root viable and "snap" when broken? To what depth do they penetrate? What is the existing root pattern, are they confined to the cracks in the soil and unable to penetrate the soil matrix? Is the soil difficult to penetrate with a knife or break between your fingers? Look at the soil structure to determine if it is massive or if it easily breaks down under the pressure from the thumb and forefinger. Answers to the above will yield valuable information on soil density. In general, critically observe profile conditions and seriously consider obtaining soil samples for laboratory analysis if unusual circumstances are observed.

It is critical that appropriate and suitable soil be provided in advance of landscaping. There are too many instances where the soil is assumed to be adequate, and in fact, it is totally unsuitable. The result is that transplants never establish but rather are in a constant state of decline or stressed condition. A quality soil is essential to healthy plantings. For example, $4.5 million was expended to acquire specimen landscape plants for a prominent site, and there was only $200,000 spent on the soil! The source of this "topsoil" was subsoil material excavated from depths at the development site and river dredging from near a power plant. These two materials became a topsoil mix!! To add to the site woes, the mix was deposited on the site at the entrance gate, and each successive load was dumped next to the previous load. In other words, each pervious load was driven over to deposit the next load seriously compacting the topsoil! Needless to say that alteration of this soil has been costly to developers, to say nothing regarding the loss of specimen plants. In fact, so many plants are having difficulty that those which have not died, have become malformed.

The lesson is, provide a suitable uncompacted soil medium prior to planting. It is virtually impossible to go back and improve a poor soil system once plants are in place and growing. Further, after many years of dealing with severely compacted conditions, I am not convinced that compaction can be relieved, that is unless one has endless funds and total control over the site activities. My experience has been that soil compacted can be identified as the initial cause or stress producing plant decline, after which, secondary stresses and disease further complicate the issue.

SOIL SPECIFICATION

A single soil specification is difficult to develop to meet all needs. Therefore, the following general specification recommends that a sandy loam soil be the material of choice because this soil texture will not normally retain excess moisture against drainage. The specification may require alterations depending upon the site soil availability, the projected use of the area, plant types proposed, and other considerations. The abbreviated general soil specification is as follows:

A. Topsoil shall be natural, surface soil, in a friable condition and contain less than 3% subsoil. It shall be free of hardpan material, stones and clods larger than 1/2" in diameter, sticks, weed seeds as specified, and other debris.

B. A certified report of test results from an agricultural experiment station or approved agricultural laboratory must accompany the soil and meet the following requirements:

1. Shall be a natural, original surface soil or a <u>sandy loam</u> texture with a mechanical analysis of 60-65% sand, 15-25% silt, and 10-15% clay.
2. Shall have at least 2%, but no more than 5%, organic matter.
3. Soil pH shall be 5.5 to 6.5 inclusive unless specified otherwise.
4. Soil salinity by electrical conductivity measurement shall not exceed 600 parts per million (ppm) as determined by Black, Editor: "Methods of Soil Analysis", Part 2, published by the American Society of Agronomy, 1965.
5. The soil nutrient level shall be greater than 100 lbs/acre of magnesium, 150 lbs/acre of phosphorus, and 120 lbs/acre of potassium.

There are other stipulations as well depending upon the type of project, the plants, and other considerations.

SOIL AMENDMENT ALTERNATIVES

There are a number of suitable choices for amending urban soil conditions and each has a place in the landscape. These are generally divided into two categories, organic and inorganic.

ORGANIC. These amendments are commonly short lived in an aerobic soil system and thus may require replacement to maintain continuous benefits. A partial list of organic amendments include: compost, leaf mold, peat, sphagnum, milled pine bark, and wood chips.

Organic material should be used with caution in compacted soil situations. The major problem encountered is that some materials will absorb up to 400% of their own weight in moisture. Should this occur in a poorly drained situation, anaerobic soil conditions may result causing plant death. Also, soil moisture should be evaluated prior to providing supplemental watering of beds where organics have been used. In general, the recommended rate of incorporation of organics with a soil is 5 to 10% by volume. It may not be advisable to incorporate organics throughout the entire manufactured soil profile, rather restrict the organic addition to the surface six inches. In natural profiles, the organic matter content usually drops off within the surface four to six inches. Should it be incorporated at depth in profile, this could easily result in subsurface saturation.

A method to maintain the organic matter content on a soil is to topdress. This function may follow maintenance aeration, dethatching, or in some cases be applied directly to the soil surface. The amount used for topdressing at different rates are summarized in the following table:

ORGANIC MATTER TOPDRESSING RATES

Depth inches	Cubic Yards	
	per 1000 sq. ft.	per acre
4	12.4	538
3	9.3	404
2	6.2	269
1	3.1	135
1/2	1.5	67
1/4	0.77	34
1/8	0.38	17

Another consideration is the use of material such as wood chips and leaves. Each must be composted prior to use. For example, if fresh wood chips are applied to a soil, the soil nitrogen can be severely depleted causing plant chlorosis. Microbes necessary for breakdown of the high cellulose content of chips require considerable nitrogen added to the soil as a food source. It is wise to add supplemental nitrogen when applying composts. The amounts vary because of the organic matter source being used and the extent to which it has been composted.

Sewage sludge composts have become readily available in recent years and can provide excellent organic matter sources for many landscape uses. The local compost in the Washington area produced from the dewatered filter cake sludge, is highly alkaline with a pH commonly between 7.4 and 7.8. In addition, this pH is highly buffered meaning that it is very stable and virtually impossible to lower. Therefore, if the material is used on acid soils, the pH of the soil / compost mix will raise considerably and may produce a fine soil for non-ericaceous plants. The product is particularly good for use with turfgrass or for establishing vegetation on barren sites. The site manager need to KNOW the chemistry of the compost and the soil before using the material. If possible, several trial mixes of ingredients should be evaluated in advance of field implementation. For example, if too much compost with a highly buffered pH is added to a soil system, serious consequences may result to sensitive plants. Sludge composts are generally very beneficial as soil additives to urban soils because they provide essential micronutrients as well as the normal fertilizer elements. An added benefit is the slow release of these nutrients over several years.

Organic materials provide many benefits to soil system. They will enhance the cation exchange capacity of the soil to which they are added providing for greater retention of plant nutrients. They enhance soil structure, increase tilth, and moisture holding capacity. Organics provide a valuable food source for earth worms and other microflora which significantly benefit soil structure.

INORGANIC. Several of these products are referred to as lightweight aggregates. A partial list of suitable materials include: expanded slate, calcined clay, expanded shale, sintered fly ash, porous diatomaceous earth, and course angular sand (1 to 2 mm).

The major benefits of inorganic materials are they provide a means of resisting the adverse effects of soil compaction and are residual or long-lived when homogeneously incorporated into a soil system. My research indicates that a one time incorporation of an amendment into a soil of a heavily used playground will provide lasting benefits for 20 years or more with no additional treatment (Tables I and II). If the initial data are correct, then these products my prove to be highly significant for use as a long term amendment to resist compaction. The benefits include: residual nature, inert, and provide internal product porosity. Also, by incorporating the proper amount into the soil, they resist compaction. The amounts required depend upon projected use of the site, frequency of site maintenance, and existing soil conditions. In general, the recommended range of application is between 5 and 50% by volume. As can be seen in Tables I and II, favorable results were obtained using 20 and 33% by volume.

Many of the products contain internal pores within individual aggregates. It is thought that this pore space provides additional water holding capacity but this is yet to be verified. The exception to this is sand. A word of caution for sand, **DO NOT** use a mixed grade sand and expect to improve soil conditions. In fact, "concrete-like" soil results. The key to using sand is use **ONLY A COARSE ANGULAR** sand of 1 to 2 mm in size and in volume percentages of 85% or more!

Site assessment and projections of site use are the primary factors influencing what and how much soil amendment is required to sustain plant vigor. Maintenance and the frequency of attention will also influence the choice of materials.

URBAN PLANTING

It has been stated that the average life expectancy of an urban tree is only 7 years (American Forestry Association, 1992. Figure 1)! This is not an encouraging tribute to our success as urban plant professionals. However, the traditional source of many of our urban plants have been our forest resources and these conditions are diametrically opposed to planting conditions encountered in urban areas. Therefore, we must understand the conditions into which we are transplanting and providing suitable site conditions for selected plants. Another consideration is the design life for a landscape should be determined in advance of planting so that appropriate conditions are provided and maintained.

A COMMON PROBLEM. Too often street tree plantings are located in a 4x4x3 ft coffin which offer no hope for lateral or deep root expansion because of severely compacted side walls and planter bottoms. These soil pits are edged by concrete walks and curbs. Also, there is no means of removing excess moisture as it accumulates in the bottom of the pit resulting in a "tea cup" like condition. Plants are at the mercy of the site. In addition, a serious planting situation is created when the plant holes are dug into compacted soil, balled and burlapped stock place into the hole, and "selected backfill" placed around the rootball. The problem is that two soil lithologic discontinuities are created at the interface of the rootball/selected backfill, and at the select backfill/site soil. These discontinuities result in complex physical barriers to air and water movement seriously complicating the survival of the transplant. The select backfill has been designed to be porous and yet retain moderate moisture levels for the plant. However, the result is this soil easily becomes saturated resulting in an anaerobic environment because excess moisture cannot escape from the pit.

If the planting site cannot be enlarged and proper soil provided, then it is recommend to reuse the excavated soil from the pit and amend it slightly with organic matter and/or fertilizer. The exact amount should be determined by soil testing. This slightly amended backfill should be replaced in the planting hole so that the natural root crown rests 3 to 4" above the surrounding soil level. The soil at the base of the pit must be firmly tamped to maintain the rootball at this elevation preventing its subsidence into the planting medium. Off pavement runoff should be prevented from entering the tree pit.

ROOT DEVELOPMENT. Plant roots are opportunists and will choose the path of least resistance. Therefore, if a suitable soil medium is provided, the root will tend to remain until the confines of that medium or area of modified soil or when they find a "break out" into a favorable area. For example, if a tree is within the curb/sidewalk confines and is able to find an escape beneath the sidewalk into the lawn area behind, it will often take advantage of the escape path. Contrary to belief, I have not noticed tree roots growing beneath large paved area such as streets because the environment is usually anaerobic, soil densities high, and pavement essentially seals off this environment.

A MISCONCEPTION. The educational message which has been inappropriately taught in the past is that the root system of a tree reflects the shape of the above ground tree crown. This is not true! Root systems of trees naturally expand **laterally** in the surface soil with 80% or more of the root system remaining in the surface 18" of the soil. Only the support roots will tend to grow to depth if the soil conditions are favorable. Perry, 1982 has indicated that tree roots will extended laterally in favorable soil to 3 to 4 times the diameter of the crown of the tree. That is, a 20' diameter crown of a tree may have surface root existing up to 80' from the trunk of the tree! Thus, when attempting to preserve and existing tree, the lateral extent of the root system must be known.

DRAINAGE

Site drainage is a critical consideration for urban sites. Too often, well-drained soil mixtures are specified for use in transplanting and there is no means provided for removing excess moisture which accumulates in the soil mix. Excess moisture held within the planting hole can result in either anaerobic or saturated conditions and plant death. It is usually recommended that drainage be designed into a planting site prior to construction and tested before adding the soil mix. It is very difficult if not impossible to install drainage after the landscape design is completed without major disruption of the site and the transplants. Also, if growth is initiated, serious root damage may result by attempting to install drainage. It is critical to understand that water can always be added to a planting site, BUT, it cannot always be removed!

The best method to handle drainage systems, if it can be accomplished, is to allow gravity to be the moving force and outlet the system to daylight. This type of system can be easily checked for functionality. For in-pavement situations, perhaps the best system is to access a sewer and outlet the drainage into this system. It must, however, be protected with back flow preventative device so that water will not back up into the planter during demand situations. In any event, which ever system is selected, they should be field checked before being backfilled. Unfortunately, a drainage system, once installed, is very difficult to access again to check that it is functioning as designed.

TRANSPLANTING TECHNIQUES

NURSERY STOCK

When tagging trees or shrubs in the nursery, be sure that the original root crown exists at the soil surface. Too often the natural crown is buried because of soil which became deposited upon it during digging of an adjacent tree; or, during cultivation, soil is windrowed over the root crown. The "short" ball is a very common occurrence when dealing with balled and burlapped, or spade dug stock. A short ball results because of excess soil being placed over the natural root crown. The situation can be easily avoided in the nursery simply by checking the location of the natural root crown of the plant, and if excess soil is found. insisting that it be removed before digging the plant. In each instance, if a tree is dug without this knowledge, a large portion of the root system will remain in the nursery after digging. This can be significant when one considers that a tree spade dug tree on average takes with it to the new planting site **only** 3.8% of its original root system (Watson, 1983). When transplanting at the new site, set the rootball of the tree 3 to 4" above existing grade by providing a pedestal under the ball to support it against subsistence in the planting hole. It is important that the best conditions be provided for the transplant and that the plant be in acceptable condition when received at the landscape site.

SHARED ROOTING SPACE

This technique is probably the preferred transplanting situation for urban trees (METRIA:5, 1985). The technique implies preparing an enlarged planting area into which several plants are placed. These plants are able to share the common root space and each provides protection for each other. The configuration of the space can take on many shapes depending upon the location. The space between the curb and the sidewalk may be excavated the length of the block providing linear configuration and allowance for root expansion. This is particularly important when we consider the composition of a tree.

COMPOSITION OF A TREE

Leaves	5%
Branches	15%
Stems	60%
Large roots	15%
Fine roots	**<5%**

There are three basic configurations which utilize the shared rooting concept:

1. THE MOUND SYSTEM. This technique is very beneficial for a compacted site. If the compacted subsurface can be crowned in the center and tapered toward the edges this will allow for gravity drainage at the base of the mound. The slope of the crowned subsurface should be about 3% to provide lateral drainage in response to gravity. The edges of the bed should be feathered to permit lateral drainage. Over the contoured subsurface, a suitable planting medium is placed. It too should be feathered at the edges. The rule of thumb is to allow minimum of 18" of soil for trees, 12" for shrubs and annuals, and 6-8" for turfgrass.

2. THE RAISED BED. This system utilizes a walled perimeter of masonry, wood, etc., which rises 6-12" or more above the adjacent sidewalk. Internal drainage should be installed to remove excess water from the bed. Into the bed is place a homogeneous soil specifically blended for the selected plants. The raised bed provides the plantings with protection from pedestrian traffic and space for seating on the wall.

3. AT-GRADE PLANTER. Usually for this planter, an excavation is made into a site to remove undesirable soil to a depth of at least 18". The material is removed from the site. The subsurface should be graded and compacted to crown the center and sloped toward the edges. Drainage must be provided along the edges to remove excess moisture. A homogeneous soil is required to support the selected plants, placed into the bed, and it may or may not be crowned.

In both mound and at-grade planters, a small curb or post-n-chain could be used to direct pedestrians around the beds reducing undue impact upon plants.

Each system, must provide uniform soil, drainage, and the shared rooting space. As mentioned, the configuration depends upon the site, space and innovation of the designer.

A planting technique which is applicable for restricted urban and road median locations is to flare out the edges of the tree pit into the site providing additional amended rooting area. At the base of the planting hole, a pedestal is left to support the rootball several inches above the surrounding grade. The concept is to provide space for vital surface roots to rapidly initiate growth. Even though this condition is less than desirable, it is a method to allow for rapid root extension when options are limiting. A pedestal should remain beneath the rootball for support and one might consider small stature tree selections.

The Landscape Design

The key to a successful landscape design is through review of the project early in the design concept with a multidiscipline team to eliminate flaws such as poor plant selection or poor soil; inappropriate soils for supporting the plants; existence of poor drainage conditions; compacted or layered soil; insist upon proper planting dates / seasons; etc. Again, during construction, it is very important to have a trained contracting officer on site during the entire implementation of the project. This individual must have the power to halt the project if something is not as specified.

Soil Placement

The soil should be mixed or prepared off site and imported to the project area. It is also vital to the success of the project that all amendments and soils are thoroughly blended to form a homogeneous mix. In some instances it is desirable to blend the mix with the subsoil at the contact to eliminate the production of a lithologic discontinuity at the base of the planter. Once the material arrives at the project, it should be placed in the most distant corner from the entrance and each successive load placed next to the previously placed soil. The objective is to work out of the site without tracking over previously placed soil. Undue compaction must be avoided. In general the specified compaction level should be about 70 - 85%. Some sites witnessed have been compacted top 95% or more! This fine for support of buildings and roadways but totally unsuitable for landscape purposes. The soil materials must be placed into the site as uniformly as possible to eliminate layering of dissimilar soil materials.

Maintenance

Any site that will be subjected to heavy visitation will require careful attention to maintenance. It would be beneficial to restrict sensitive areas from visitor impact by using post-n-chain or some other exclusion method. For heavily trafficked areas, soil aeration must be anticipated to lessen the adverse effects of compaction. Certainly, during the design phase, some attention should be given to using light-weight aggregates to resist compaction if it will become a problem. Otherwise, soil aeration equipment should be considered for aerifying the soil. This should be done at least four times annually or more frequently if site use is especially high. Some sites may require monthly aeration during heavy use. To achieve this, there are two basic aerifiers which perform well on compacted sites. The first is the shatter aerator which inserts "arrow-head" like blades into the soil between adjacent tines opening lateral fractures. This equipment is very basic in design, capable of covering large acreage in a relatively short time, and effectively penetrates compacted soils to about 8". Up to 2000 lbs of weight can be used to achieve full probe penetration.

The other aerator is the deep core or tine aerator which opens vertical holes in the soil by removing either soil cores or by forcing a probe into the soil. At the point of maximum insertion, there is a deflection of the tip of the probe fracturing the subsurface. This equipment is slow moving and thus covers less acreage daily. Another disadvantage is that it is mechanically complex and breakdown occur on heavily compacted and dry soils. The major advantage of the equipment is that it penetrates the soil 10" with the coring attachment and up to 16" with the probes. This can be a major advantage for soils which are compacted to depth. Perhaps a desirable approach would be to use this aerator on the site once annually and the shatter aerator for the remaining monthly treatments.

Another recent development has been the use of compressed air to fracture subsoils. There are two basic types of equipment but they essentially function in the same manner. That is, access holes are drilled into the soil, the aeration probe is inserted into the soil totally filling the void. Alternate injections of air and water are used under 150 psi to fracture the subsurface soil. Once fractured, a soil amendment such as the ceramic diatomaceous earth can be injected into the voids to maintain their open configuration.

At present, this technique is still under research evaluation to determine its effectiveness upon the soil and plant root systems. Also, the proper amendment is still open to question. The technique is very slow and best suited for a tree by tree application. Also, with air pressures this high, great care is required to insure personal safety.

Conclusions

When dealing with urban sites, each requires individual assessment and treatment because conditions are so variable. There are a number of rules of thumb which can be used to address problem situations and a number of these have been presented in this paper. One must usually select specific site options from a pallet of alternative procedures that have worked in the past and select the best solution for the site in question. Certainly, our challenges are many and the potential solution to an individual location may be a best guess approach. If we are observant and select options from our experience, carry them out properly, and follow-up with proper maintenance, favorable results will usually follow. Personally, I feel that this science is an observational science and we develop solutions based upon what works in other situations.